ASSESSMENT OF MOVEMENT OF WASTEWATER FROM THE CITY OF IONE'S WASTEWATER TREATMENT FACILITY INTO SUTTER CREEK

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1.0 Introduction and Background

The City of Ione's wastewater treatment facility (WWTF) is located on the south bank of Sutter Creek in a small valley west of Ione. The WWTF includes four treatment ponds and three larger percolation ponds. The Central Valley Regional Water Quality Control Board (RWQCB) has asserted that some of the effluent seeps through the levee along the north edge of the percolation ponds and directly enters Sutter Creek.

Substantial hydrologic and water quality data has been collected during the past decade for compliance monitoring. The primary focus has been on patterns and trends in groundwater levels and quality near the WWTF. Studies were also completed for the Ione WWTF Master Plan draft environmental impact report (MHA/RMT 2009).

The primary objective of this report is to summarize and interpret the available water quality and hydrology data, along with recently collected stable isotope data, in order to determine whether wastewater is moving from the WWTF ponds into Sutter Creek and, if so, the relative degree of effect on water quality within the creek. We evaluated the following data.

- Stable water isotope data for samples collected from the WWTF ponds, Sutter Creek and groundwater monitoring wells.
- Water quality data for samples collected in Sutter Creek
- Stream flow measurements in Sutter Creek.
- Sutter Creek seepage surveys
- Water budget information for the WWTF ponds.

2.0 Methods and Data Sources

2.1 Water Isotopes

Stable isotopes of hydrogen and oxygen can be used to differentiate water sources. The hydrogen and oxygen atoms that combine to form water molecules exist naturally in different forms (isotopes). Stable isotopes of hydrogen and oxygen, deuterium (D) and oxygen-18 (^{18}O), are not radioactive and do not change composition over time and, therefore, provide reliable information about water sources. Water molecules containing these isotopes are primarily $DH^{16}O$ and $H_2{}^{18}O$, which have larger atomic masses than the most abundant $H_2{}^{16}O$. The amount of deuterium and ^{18}O in a water sample is expressed as a ratio relative to the amount in a standard (Standard Mean Ocean Water) on a parts per thousand (per mil) basis.

The analysis of stable isotopes in a water sample will result in negative values if the sample has less deuterium or ^{18}O than the standard ocean water. This is the case for all the sample results presented in this report for the Ione site.

Temperature, altitude, and distance from the ocean affect the isotopic composition of precipitation. Precipitation that occurs nearer the ocean and at lower elevations has a higher amount of the heavy isotopes (deuterium and oxygen-18) than precipitation that falls further inland and at higher elevations. This variation in isotopic signatures can be used to differentiate water that precipitated locally from imported water that precipitated further inland at higher elevations[1]. In California, Ingram and Taylor (1986) and Williams and Rodoni (1997) documented the isotopic shift in precipitation owing to cloud movement inland from the coast[2].

In November 2010, HydroFocus, Inc. collected samples for determination of water isotopes from five Ione wastewater ponds, monitoring wells MW-1 and MW-1A, and Sutter Creek sites SC4 and SC2 (**Figure 1**) A sample was also collected from the Amador Transmission Pipeline at Tanner Reservoir to represent the City of Ione's water supply.

2.2 Sutter Creek Water Quality

During 2005 through 2008, the Ione Chief Wastewater Operator collected Sutter Creek water samples at two locations (**Figure 1**). Starting in 2009, Condor Earth Technologies, Inc. personnel collected samples at the same locations. Sample location SC3 is located downstream at the downstream edge of the WWTF, at the 5-mile Road Bridge. Sample location SC4 is located at a utility bridge about 400 feet upstream of the WWTF. Samples were also collected at a third site 400

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[1] Extensive research documented in peer-reviewed scientific literature demonstrated the effects of altitude temperature and distance inland on isotopic composition. For example, Gat, J.R. and Gonfiantini, R. (1981) edited "Stable Isotope Hydrology, Deuterium and Oxygen-18 in the Water Cycle" documented the results of decades of research on observed variations of these isotopes in the environment.

[2] Ingram, N.L., and Taylor, B.E., 1986, Hydrogen isotope study of large-scale meteoric water transport in northern California and Nevada, Journal of Hydrology, 85, 183-197
Williams, Alan E. and Rodoni, Daniel P., 1997, Regional isotope effects and application to hydrologic investigations in southwestern California, Water Resources Research, Vol. 33, No. 7, 1721-1729.

feet downstream of SC3. The site is identified as SC2, although it differs from the SC2 site used in previous studies (which was about midway between the current SC2 and SC4 locations and near the upstream edge of Pond 4). **Figure 1** shows the locations of the WWTF ponds and creek sampling sites.

Field and laboratory parameters were measured for each water quality sample and entered into the database, although the number of parameters and total number of samples collected since 2003 varies by location. We applied a nonparametric statistical test (Wilcoxon paired-sample signed-rank test) to determine whether differences in concentrations between the two sites are statistically significant (**see Appendix A**).

2.3 Sutter Creek Flow and Groundwater Levels

During the spring and summer of 2007, Balance Hydrologics estimated Sutter Creek discharge on three occasions (6/8/07, 7/6/07 and 7/16/07) by measuring velocity and depth on cross sections immediately upstream and downstream of the WWTF. On November 18, 2010, HydroFocus, Inc. measured discharge at essentially the same locations using similar methods.

Depths to water in monitoring wells are routinely measured on a quarterly basis using electric sounders (typical accuracy +/- 0.02 foot) pursuant to monitoring requirements included in the permit issued by the RWQCB to operate the WWTF. Wellhead elevations were previously surveyed by a licensed surveyor and reported to a precision of 0.01 foot, which allows depths to water to be converted to groundwater elevation. Stream elevations were read from graduated staff gages similarly surveyed and referenced to sea level.

Average monthly pond freeboard is recorded by the WWTF operators. These values are converted to water surface elevations and listed in the quarterly groundwater monitoring reports.

The precision of the water level measurements is much smaller than the typical elevations between pond stages, monitoring well waterlevels and the creek stages. Therefore, measurement error probably does not contribute significant uncertainty in comparing water levels and gradients. Contour maps of groundwater elevation are included in the quarterly monitoring reports for the WWTF.

2.4 Sutter Creek Seepage Surveys

Field evidence of seepage from the WWTF ponds through the levee and into the creek channel was first reported in 2000, when RWQCB staff observed a wet spot on the creek side of the levee[3]. A geotechnical study of the pond levees in summer 2002 also documented seepage and reported an estimated flow of 173 gallons per day, or 0.00027 cfs (WKA 2003). Concrete riprap was subsequently placed along the south bank of the creek. Balance Hydrologics staff walked along the south side of the Sutter Creek stream channel several times between June and September of 2007, searching for evidence of persistent seepage into the creek. They identified and noted only one small area of several square feet of damp soil.

2.5 WWTF Water Budget

We used monthly inflow to the WWTF reported in the City of Ione Wastewater Treatment Plant annual reports, precipitation data from the weather station at Pardee Reservoir and regional reference evapotranspiration (ETo) estimates from the California Irrigation Management System (CIMIS) to estimate total seepage from the WWTF ponds using Equation (1) below:

> Equation (1): Seepage = WWTF inflow + precipitation – evaporation +/- storage change

The equation provides an estimate of total seepage from Ponds 1 through 7 combined.

Two assumptions implicit in the calculations generate uncertainty in the results:

- Estimates of rainfall and ETo from off-site gauges or regional weather data may not represent the actual values at the WWTF.
- The average monthly total ETo estimates from CIMIS may not represent actual monthly pond evaporation.
- Pond evaporation estimates using ETo were not adjusted to represent pan evaporation or pan-to-lake coefficients.

3.0 Results and Discussion

3.1 Water Isotopes

The isotopic compositions and field parameters for samples from the ponds, Sutter Creek, monitoring wells, and Amador Transmission Pipeline/Tanner Reservoir are shown in **Table 1** and the isotopic results are plotted on **Figure 2**. Background for interpreting these results in general and for site specific conditions at the WWTF are discussed below.

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[3]MHA/RMT. August 2009. Ione WWTF Master Plan, draft environmental impact report. San Mateo, CA. Prepared for City of Ione, CA. p. 3.1-13

The ratio of deuterium to ^{18}O in rain water tends to remain constant, so that plots of δD versus $\delta^{18}O$ fall on a straight line called the meteoric water line (see purple, diagonal line in **Figure 2**). Inland, rainfall at relatively high elevations plot toward the lower-left end of the line (the more negative δD and $\delta^{18}O$ values indicate a relatively greater abundance of lighter isotopes and are referred to as being "depleted" in the heavier isotopes). In contrast, rainfall that falls near the coast and/or at relatively low elevations plot toward the upper-right end of the line (the less negative values of δD and $\delta^{18}O$ indicate a relatively greater abundance of heavy isotopes and are referred to as being "enriched" in the heavier isotopes).

When water evaporates, the liquid remaining becomes progressively "heavier" or enriched. That is, the δD and $\delta^{18}O$ values both become progressively less negative. However, because the water molecules containing ^{18}O are heavier than those containing deuterium, during evaporation they diffuse to the atmosphere more slowly than water molecules containing deuterium. Therefore, there is an increase in the ^{18}O relative to deuterium and the isotopic composition plots on a line with a lower slope than the meteoric water line. In other words, evaporation causes the stable isotope results to plot along a line trending upward and to the right, but at a lower slope than the meteoric water line (see black, diagonal line in **Figure 2**). The evaporative effect on the isotope composition is well documented in the literature, and these evaporative trend lines typically have slopes that range from 3 to 6 for the $\delta D/\ \delta^{18}O$ equation.[4]

Points representing Sutter Creek water, site groundwater, and the municipal water supply (Amador Transmission Pipeline) plot on or close to the meteoric water line shown in **Figure 2**. The meteoric water line is defined by the equation $\delta D = 8.0 \times \delta^{18}O + 10$. The isotopic composition of Amador Transmission Pipeline sample plots toward the lower left of the line indicating it is depleted in ^{18}O and deuterium as would be expected for water that originates as precipitation in the Mokelumne watershed east of Ione.

Wastewater treatment starts in pond 1 and moves sequentially through ponds 2 to 5. Pond 6 was drained for maintenance during the time of sampling and, therefore, not sampled. The wastewater sample from pond 1 is similar to the municipal supply sample because evaporation is limited during normal municipal use (Figure 2). The results for samples from wastewater ponds 2 through 5 indicate increasing enrichment with the heavier isotopes, which is consistent with progressive evaporation. The ^{18}O composition of the pond samples ranged from -8.3 ‰ to -11.3 ‰ and the deuterium composition ranged from -68.5 ‰ to -81.3 ‰. All of the wastewater pond sample results plot on a line defined by the equation $\delta D = 4.58 \times \delta^{18}O - 29.31$. The origin of this line is the municipal water supply sample (Amador Transmission Pipeline), and the slope is lower than the meteoric water line as is expected because the wastewater undergoes partial

[4] See Gat, J.R. and Gonfiantini (Eds.). 1981. Stable isotope hydrology-Deuterium and oxygen-18 in the water cycle, Tech. Rep. Ser. International Atomic Energy Agency, 210.

evaporation as it moves from pond 1 to pond 5. The field measured pH also increases from pond 1 to pond 5 and conductivity decreased slightly.[5]

Table 2. Sample Isotopic Composition and Field Parameter Values, November 18, 2010.

Site	δ18O (‰)	δD (‰)	Temp (°C)	Conductivity (μS/cm)	pH	Dissolved Oxygen (mg/L)
MW 1	-8.4	-59	18.02	280	6.78	1.75
MW-1A	-8.4	-65	17.53	426	6.75	0.26
Pond 1	-11.3	-81	14.98	464	7.27	2.85
Pond 2	-11.0	-80	14.40	447	7.84	9.52
Pond 3	-10.7	-77	13.12	425	7.63	9.40
Pond 4	-10.1	-75	14.75	395	8.26	13.07
	-10.2	-75				
Pond 5	-8.3	-68	16.22	342	8.91	13.87
SC 2	-8.6	-61	11.73	280	7.43	10.67
SC 3	-8.7	-62	11.82	278	7.36	10.92
SC 4	-8.8	-61	10.21	268	6.38	10.80
TR 1	-12.5	-87	12.23	33	7.74	10.21

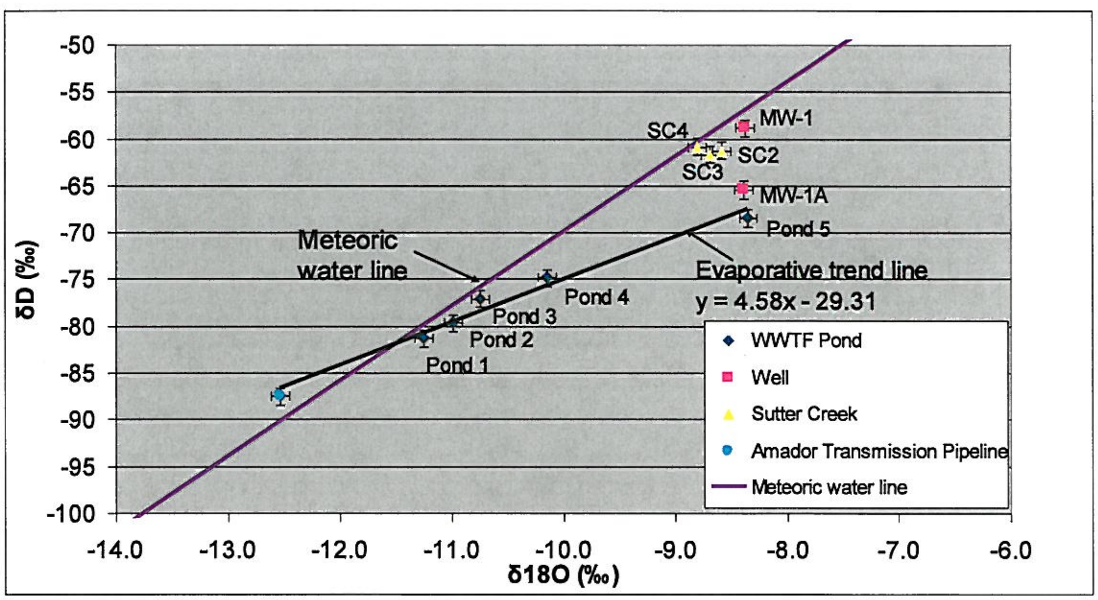

Figure 2. Isotopic Composition of Pond, Well Water, Sutter Creek, and Amador Transmission Pipeline samples collected on November 18, 2010. Error bars represent analytical precision.

[5] The increased pH value is likely the result of CO_2 consumption by algae. This may have also resulted in calcium carbonate precipitation which would explain the decrease in electrical conductivity.

The Sutter Creek and MW-1 samples plot on or close to the meteoric water line and close to each other indicating stream flow and groundwater both derive from the same source (local rainfall) and have undergone minimal evaporation. The three creek samples (SC4 – upstream of the WWTF, and SC3 and SC2 – initial downstream and further downstream sites, respectively) have isotopic signatures that are not statistically different relative to the analytical standard deviation provided by the University of Arizona laboratory. (i.e., they plot very close to each other in **Figure 2**). This means that samples collected upstream and downstream of the WWTF are not statistically different in isotopic composition. Conversely, all pond samples have an isotopic composition that is distinct from that of the creek water. If WWTF pond seepage was entering the creek, the isotopic composition of water from the SC3 and SC2 creek sampling locations would plot in between SC4 (the upstream creek sampling site) and the pond source seeping into the creek. Because the data does not show this but, rather, shows that the upstream and downstream creek isotopic values are statistically the same, we conclude that pond seepage, if any, is insufficient in magnitude to influence the stable isotope results. The sensitivity of isotope results to potential pond seepage is discussed later in this report.

3.2 Sutter Creek Flow and Groundwater Levels

3.2.1 Sutter Creek Flow

Table 2 shows measured Sutter Creek flows at sites located upstream and downstream of the WWTF on June 8, July 6 and July 16, 2007 and on November 18, 2010. The three 2007 measurements indicated small increases in flow between the upstream and downstream sites. Data sheets were not available for the 2007 measurements, so we assessed measurement uncertainty using U.S. Geological Survey methodology and component uncertainties in depth, width, and velocity (Sauer and Meyer, 1992)[6]. Results showed that two of the three 2007 data sets indicate flow changes that are smaller than the estimated measurement uncertainty and, therefore, cannot be considered significant (June 8 and July 16). The flow changes indicated by the July 6 measurements are greater than the measurement uncertainty and therefore are considered significant. The field sheets for the November 2010 measurements are provided in **Appendix B**, and the measurement uncertainty is assumed similar to the uncertainty in the data collected on June 8, 2007 because measurement methods and flow magnitudes were about the same. Accordingly, the calculated November 2010 flow difference is probably less than the measurement uncertainty and, therefore, not statistically significant.

In summary, only one of four flow measurement pairs during spring, summer and fall demonstrate a significant increase in flow along the reach adjacent to the WWTF (July 6, 2007). The July 6 measurements indicated a 0.11 cfs increase in

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[6] Sauer, V.B. and R.W. Meyer. 1992. Determination of error in individual discharge measurements. Open-File Report 92-144. U.S. Geological Survey.

flow between SC4 and SC2. Riprap and vegetation cover large portions of the lower south bank of Sutter Creek. However, seepage would have been visible as flowing water or damp spots on the soil and/or concrete riprap. Balance Hydrologics staff walked along the south side of the Sutter Creek channel several times between June and September 2007 and noted only one small area of several square feet of damp soil. This damp soil area is insufficient to explain 0.11 cfs of seepage (almost 50 gpm), and therefore not a reliable confirmation of seepage into the creek.

Table 2. Sutter Creek Flow Measurements near WWTF

Date and Source	SC4 (upstream) (cfs)	SC2 (downstream) (cfs)	Change (cfs)		Measurement error (cfs) [%]
			(cfs)	(%)	
6/8/2007 (Balance)	3.21	3.34	0.13	3.97	Est. 0.2-0.3 [8]
7/6/2007 (Balance)	0.24	0.35	0.11	37.29	Est. 0.02 [10]
7/16/2007 (Balance)	0.31	0.32	0.01	3.17	Est. 0.03 [10]
11/18/2010 (HydroFocus)	4.05	3.55	-0.5	-13.16	0.23-0.31 [7-8]

3.2.2 WWTF Water Budget

Appendix C presents monthly values of inflow, precipitation, evaporation and storage change for the ponds which was used with Equation to calculate the seepage rate from Ponds 1 through 7. The annual average seepage rate from Ponds 1 through 7 combined during 2008 was 0.49 cfs, and the monthly rates varied by plus or minus 0.3 cfs. These calculations indicate that total pond seepage is on the same order of magnitude as typical Sutter Creek flow during the late summer months. However, measured flows indicate little or no changes in creek flow as it passes by the WWTF.

3.2.3 Groundwater levels

We estimated groundwater-flow directions beneath the ponds and adjacent groundwater areas using triangulation methods. In this method, the direction of groundwater flow can be determined using groundwater elevation data from a minimum of three wells[7]. Groundwater elevation is calculated at points along the sides of a triangle connecting the three well locations and contours drawn between points of equal elevation. The flow direction is assumed perpendicular to the contour lines.

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[7] Driscoll, Fletcher G., Ph.D., 1986, Groundwater and Wells, Second Edition, Johnson Division, St. Paul, MN.

Figure 3 shows inferred quarterly groundwater-flow directions (Fourth Quarter 2009 and First through Third Quarters 2010). North of Sutter Creek, inferred groundwater flow is consistently from the northeast to southwest towards Sutter Creek. Inferred groundwater flow beneath treatment and percolation ponds 1 through 4 is to the southwest, either away or almost parallel to Sutter Creek. Similarly beneath ponds 5 through 7, inferred groundwater flow is to the west and southwest, either away or parallel to the creek. The predominant flow direction to the creek is therefore from the north, whereas south of the creek flow paths are spatially variable. Groundwater seepage may occur to some extent from the south, but it depends on the magnitude of the local gradients and permeability of the water-bearing sediments.

3.3 Sutter Creek Water Quality

The Wilcoxon paired-sample signed-rank test for samples collected upstream and downstream of the WWTF indicated statistically significant differences for four of the 19 water quality parameters and dissolved constituents having sufficient sample size for analysis: sodium, chloride, boron and manganese. For each of these constituents, concentrations downstream of the WWTF (site SC2) were greater than upstream (site SC4) at the 95% confidence level. The explanation for the statistical analysis is presented in **Appendix A**.

Groundwater seepage can explain observed constituent concentration increases in the creek. **Figure 4** shows box plots[8] of chloride and manganese concentrations in creek samples and water samples from wells located between the two surface water monitoring stations (adjacent to the WWTF ponds, north of the creek, and south of the creek). Chloride is conservative and acts as a tracer for groundwater movement into the creek, and the box plots show that both groundwater beneath the ponds and north of the creek are sufficiently elevated in chloride ion concentrations to influence creek water quality. Manganese is not conservative, and its concentrations are influenced by redox conditions and precipitation reactions. The box plots show that groundwater beneath the WWTF ponds has elevated manganese concentrations relative to the other groundwater samples.

We utilized mass conservation and measured creek flows and chloride concentrations to estimate the seepage rate necessary to explain the observed chloride concentration increase in Sutter Creek between SC4 and SC2. Equation (2) below indicates the chloride flux downstream at SC2 is the result of chloride concentrations upstream at SC4 and the contribution of chloride in seepage that occurs between SC4 and SC2:

$$Q_{SC4}C_{SC4} + Q_{gw}C_{gw} = Q_{SC2}C_{SC2} \quad (2)$$

[8] A boxplot consists of a rectangular box, representing roughly the middle 50% of the data, and lines extending to either side, indicating the general extent of the data. The median value is marked inside the box, and outliers are marked outside the box beyond the extending lines.

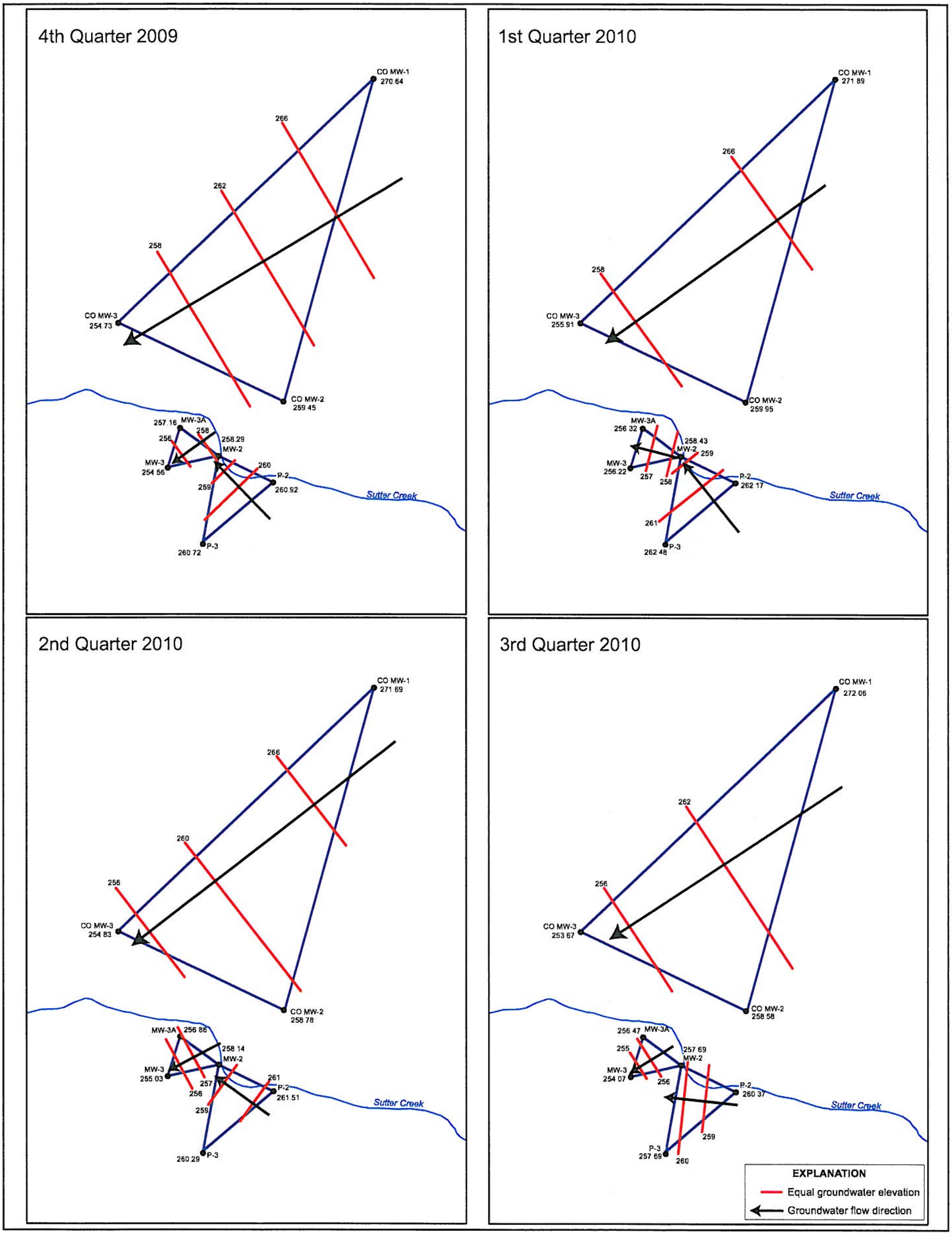


Figure 3. Inferred groundwater flow directions using triangulation method.

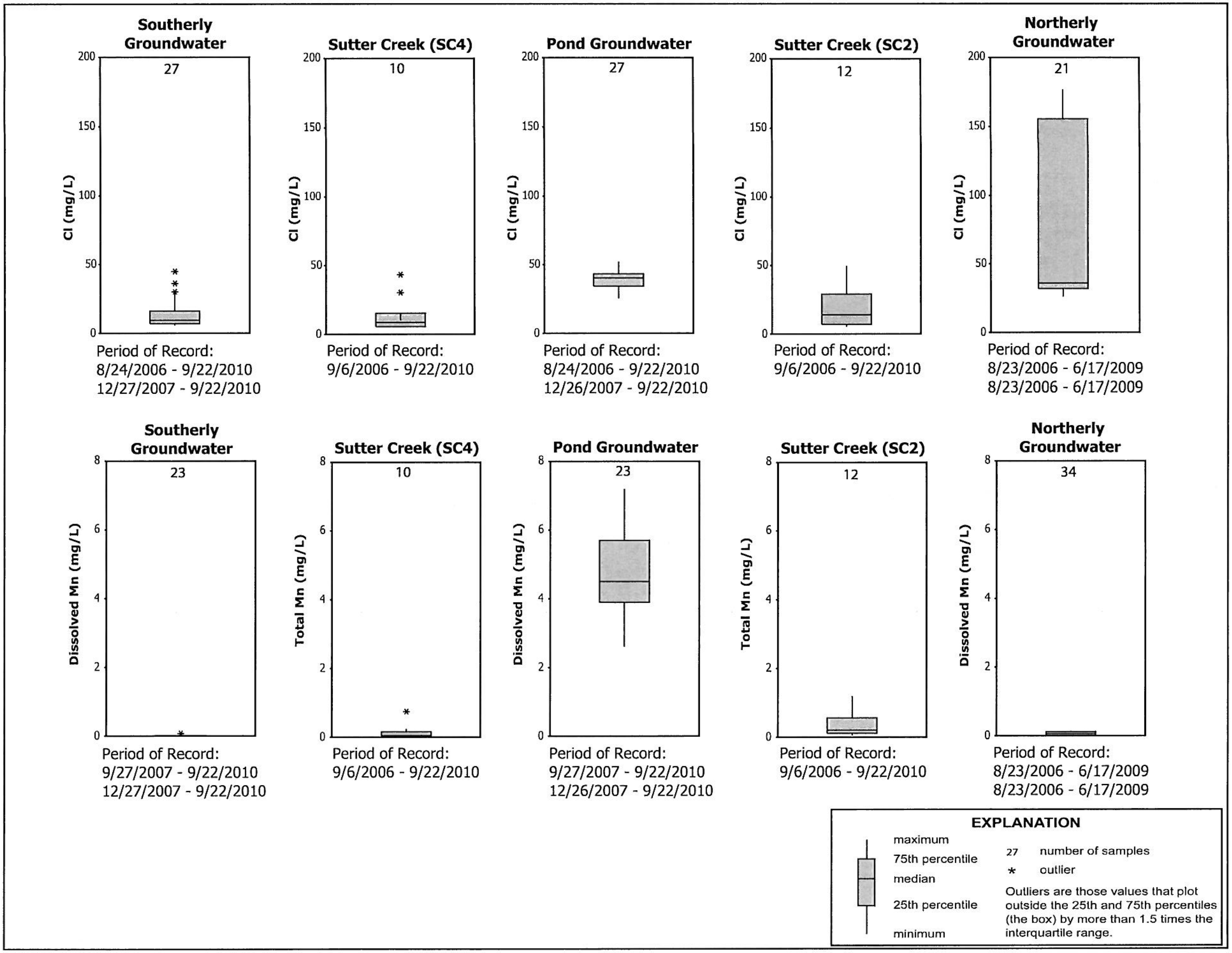


Figure 4. Box plots of chloride and manganese concentrations in water samples for potential seepage sources to Sutter Creek.

Equation (2) can be re-arranged and solved for the seepage rate:

$$Q_{gw} = [Q_{SC2}C_{SC2} - Q_{SC4}C_{SC4}] / C_{gw} \quad (3)$$

The July 6, 2007 flow measurements have the lowest relative uncertainty level and indicate a significant increase in flow between SC4 and SC2 (0.11 cfs), presumably due to seepage. The seepage source could conceivably be groundwater originating north of the creek, groundwater originating south of the creek beneath the WWTF ponds, or direct seepage of pond water to the creek. Analytical results for water samples representative of the creek flow measurement date[9] and our seepage calculations using Equation (3) are summarized below in **Table 3**.

Table 3. Calculated seepage rates using chloride ion concentrations in creek, well, and treatment pond water samples.

	Site	Date	Chloride Concentration (mg/L)	Average Concentration (mg/L)	Estimated Seepage (cfs)
Southerly Groundwater	MW-1 MW-1A	6/29/2007 6/29/2007	6.3 29	17.6	0.25
Sutter Creek	SC4	6/29/2007 8/28/2007	18 23	20.5	---
Pond Water	Pond 4	June 2007	35	---	0.12
Pond Groundwater	MW-2 MW-3A	6/25/2007 6/25/2007	30 33	31.5	0.14
Sutter Creek	SC2	6/29/2007 8/28/2007	21 32	26.5	---
Northerly Groundwater	CO-MW-2 CO-MW-3	6/19/2007 6/19/2007	154 33	93.5	0.05

Chloride concentrations indicate a seepage rate of 0.25 cfs from the south would explain the concentrations observed at SC2, however this rate is substantially greater than measured (0.11 cfs). The calculated seepage rates for treatment pond water and groundwater beneath the ponds is closer to measured (0.12 and 0.14 cfs, respectively), however both of these water sources are partially

[9] Analytical results for well water samples collected in June 2007, and average creek water samples collected in June and August 2007 were assumed representative of water quality conditions on July 6, 2007 (the creek water samples were averaged to minimize the influence of temporal variations in creek flows on the seepage calculation).

evaporated and the isotope data does not indicate their presence in the creek (**Figure 2**). **Figure 5** shows that the isotopic composition of creek water samples would have been substantially different had pond water or pond groundwater seeped into the creek at the time of sampling on November 2010.

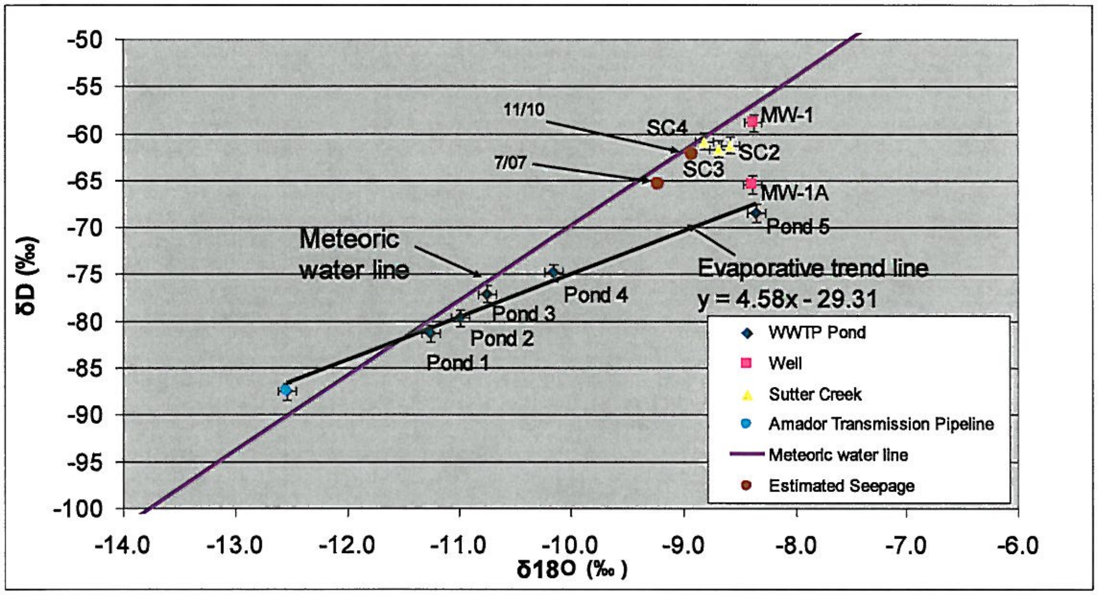


Figure 5. Calculated isotopic composition of creek water samples on July 2007 and November 2010 for a seepage rate of 0.11 cfs.

4.0 Summary and Conclusions

The isotopic composition of Sutter Creek water, WWTF pond water, area well water, and Amador Transmission Pipeline samples are distinct and can be clearly differentiated from one another. The results of this analysis indicate that that there is not an isotopic difference in Sutter Creek water samples collected upstream and downstream of the WWTF pond. The downstream creek sample showed no discernable influence from WWTF pond water seepage in its isotopic composition.

Only one of four flow measurement pairs during spring, summer and fall conditions of 2007 and 2010 showed a significant increase in flow along the reach adjacent to the WWTF (July 6, 2007). The July 6 measurements indicated a 0.11 cfs increase in flow between measurement stations SC4 and SC2, however the source of seepage is unknown. Groundwater originating north of Sutter Creek, groundwater beneath the WWTF ponds located south of the creek, or direct pond seepage are conceivable sources of seepage. Of these three, groundwater originating north of the creek seems the most likely source.

North of Sutter Creek, inferred groundwater flow is consistently from the northeast to southwest towards Sutter Creek, whereas inferred groundwater flow beneath the treatment and percolation ponds is to the southwest – either away or almost parallel to Sutter Creek. The predominant flow direction to the creek is therefore from the north, whereas south of the creek flow paths are spatially variable.

Statistical analyses of Sutter Creek water quality parameters measured on samples collected upstream and downstream of the WWTF indicated significant differences for only four of the 19 water quality parameters and constituents evaluated. The four constituents showing significantly higher concentrations downstream are sodium, chloride, boron and manganese. Chloride is conservative and acts as a tracer for groundwater movement, and groundwater north of the creek and beneath the ponds are both sufficiently elevated in chloride ion concentrations to influence creek water quality. Mass balance calculations indicated that only 0.05 cfs of seepage from the north is needed to explain downstream chloride concentrations, which is about 50% of the measured seepage to the creek In contrast, mass balance calculations indicated that a seepage rate of groundwater beneath the WWTF ponds of 0.14 cfs is necessary to explain downstream chloride concentrations. However, pond water and groundwater beneath the ponds are both partially evaporated, and isotopic data collected as part of this study indicated these water sources are not significantly influencing creek water quality.

The collective weight-of-evidence from groundwater elevation, stream discharge measurement, isotopic, and water quality assessments indicate that WWTF pond seepage to Sutter Creek is most likely negligible, and not discernably affecting the creek's isotopic composition or water quality. Rather, the concentration changes are more likely caused by seepage of groundwater originating north of the creek. The northerly groundwater flows toward the creek and has substantially higher concentrations of three of the above four constituents (sodium, chloride, and boron) relative to upstream creek concentrations.

5.0 Appendices

A. Sutter Creek Water Quality Data
B. Flow measurements and methods
C. WWTF water budget

Appendix A. Statistical Test of Water Quality Differences

The Wilcoxon signed-rank test was developed to determine whether the median difference between paired observation points equals zero.[1] The alternative hypotheses are that median differences are less than or greater than zero. The test was applied to 19 water quality parameters that are routinely monitored upstream (site SC4) and downstream (site SC2) of the Ione WWTP during 2004-2010. For each date, the downstream concentration was subtracted from the upstream concentration to obtain a difference, which was positive or negative. The statistical software MINITAB was used to calculate the Wilcoxon statistic which was then compared to a critical value depending on sample size to determine the level of significance. Table D-1 shows the results of the test. Column 6 shows the significance level for the hypothesis that downstream concentrations are greater than upstream concentrations. Four numbers in bold indicate parameters that were statistically greater downstream relative to upstream at the 95% confidence level.

Table D-1. Results of Wilcoxon Rank Sum test

Parameter	Total Number of Paired Samples	Number of Samples With Differences	Wilcoxon Statistic	Probability that H_o is true (p)	Confidence Level for Significant Difference (1-p)
Temperature	6	6	11	1	0.00%
Field pH	6	6	15	0.402	59.80%
Field EC	6	6	10	1	0.00%
Dissolved Oxygen	6	6	5	0.295	70.50%
Oxydation/ Reduction Potential	4	4	3	0.584	41.60%
Turbidity	4	4	1	0.201	79.90%
Total Coliform Bacteria (TCO)	8	3	5	0.423	57.70%
Fecal Coliform Bacteria (FCO)	7	6	9	0.834	16.60%
Nitrate (as N)	12	11	49	0.168	83.20%
Kjeldahl Nitrogen (as N)	12	8	16.5	0.889	11.10%
Total Dissolved Solids (TDS)	12	9	10.5	0.173	82.70%
Chloride	12	12	11	0.031	**96.90%**
Total Sodium	12	12	0	0.003	**99.70%**
Total Arsenic	2	2	2	1	0.00%
Total Boron	12	12	0	0.003	**99.70%**
Total Iron	12	11	21	0.307	69.30%
Total Manganese	12	11	0	0.004	**99.60%**
Ammonia	8	8	16	0.834	16.60%
Nitrite (as N)	8	7	24	0.108	89.20%

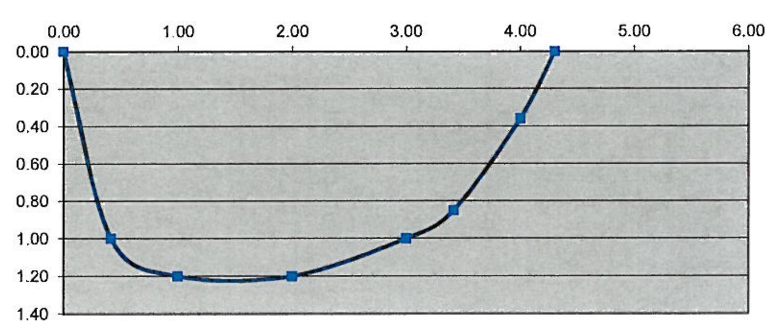
[1] Helsel, D.R. and Hirsch, R.M., 1992, Statistical Methods in Water Resources, Elsevier

Appendix B. Streamflow Calculations for November, 2010

Station: Sutter Creek, station SC-4
Date: 11/14/2010 Start time: End time:
Observer: HydroFocus
Flow conditions: Stable, fairly smooth substrate at narrow point in creek.

Weather:
Water quality:

	Distance (ft)	Width (ft)	Depth (ft)	Velocity (ft/s)	Area (ft2)	Horiz. angle factor for velocity (decimal)	Flow (cfs)
	0.00	0.21	0.00	0.00	0.000	1.00	0.000
	0.42	0.50	1.00	1.05	0.500	1.00	0.525
	1.00	0.79	1.20	1.10	0.950	1.00	1.045
	2.00	1.00	1.20	1.30	1.200	1.00	1.560
	3.00	0.71	1.00	0.80	0.708	1.00	0.567
	3.42	0.50	0.85	0.80	0.425	1.00	0.340
	4.00	0.44	0.36	0.30	0.159	1.00	0.048
	4.30	0.15	0.00	0.00	0.000	1.00	0.000
Total:	0	4.3			3.94		4.08
Average:			0.92	1.04			



MEASUREMENT UNCERTAINTY
Reference: Sauer, V.B. and R.W. Meyer. 1992. Determination of error in individual discharge measurements. Open-File Report 92-144. USGS, Norcross, GA

Substrate	
soft	5
uneven	10

DEPTH (Sd)
Enter substrate type 'stable', 'soft' or 'uneven': stable — 2.00

PULSATION (St)
Average point measurement duration (sec): 50 — 5.55

VELOCITY (Si)
Assume pygmy meter with standard rating — 1.78

VERTICAL METHOD (Ss)
Enter 1 if 0.6D, enter 2 if 0.2+0.8D: 1
Ss= 4.48

NUMBER OF POINTS ACROSS SECTION (Sv)
Sv= 5.13

HORIZONTAL OBLIQUE FLOW (Sh)
Sh= 0.00 Assumed small for vertical-axis meters

OVERALL FLOW MEASUREMENT UNCERTAINTY
% 7.49
cfs 0.31

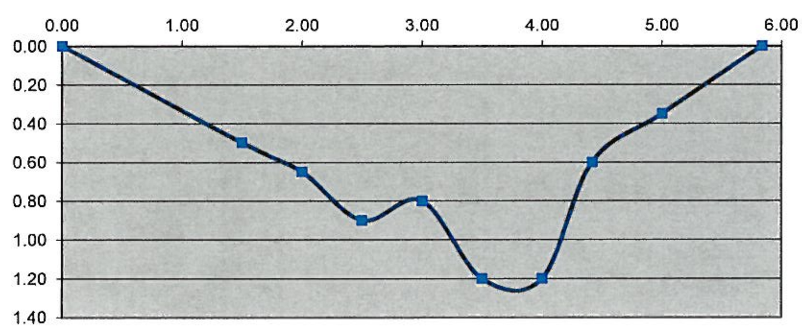
Appendix B. Streamflow Calculations for November, 2010

Station: Sutter Creek, station SC-2
Date: 11/14/2010 Start time: End time:
Observer: HydroFocus
Flow conditions: Stable, fairly smooth substrate at narrow point in creek.

Weather:
Water quality:

Distance (ft)	Width (ft)	Depth (ft)	Velocity (ft/s)	Area (ft2)	Horiz. angle factor for velocity (decimal)	Flow (cfs)
0.00	0.75	0.00	0.00	0.000	1.00	0.000
1.50	1.00	0.50	0.43	0.500	1.00	0.215
2.00	0.50	0.65	0.75	0.325	1.00	0.244
2.50	0.50	0.90	1.34	0.450	1.00	0.603
3.00	0.50	0.80	1.32	0.400	1.00	0.528
3.50	0.50	1.20	1.25	0.600	1.00	0.750
4.00	0.46	1.20	1.49	0.550	1.00	0.820
4.42	0.50	0.60	0.79	0.300	1.00	0.237
5.00	0.71	0.35	0.61	0.248	1.00	0.151
5.83	0.42	0.00	0.00	0.000	1.00	0.000
Total: 0	5.83			3.37		3.55
Average:		0.58	1.05			

SC-2 Cross Section



MEASUREMENT UNCERTAINTY
Reference: Sauer, V.B. and R.W. Meyer. 1992. Determination of error in individual discharge
measurements. Open-File Report 92-144. USGS, Norcross, GA

Substrate

soft	5
uneven	10

DEPTH (Sd)
Enter substrate type 'stable', 'soft'
or 'uneven': stable 2.00

PULSATION (St)
Average point measurement
duration (sec): 50 5.55

VELOCITY (Si)
Assume pygmy meter with
standard rating 1.77

VERTICAL METHOD (Ss)
Enter 1 if 0.6D, enter 2 if 0.2+0.8D: 1
Ss= 4.13

NUMBER OF POINTS ACROSS SECTION (Sv)
Sv= 4.22

HORIZONTAL OBLIQUE FLOW (Sh)
Sh= 0.00 Assumed small for vertical-a

OVERALL FLOW MEASUREMENT UNCERTAINTY
% 6.57
cfs 0.23

Appendix C. WWTP Pond Water Balance Calculations

	Influent Flow	Influent Flow	Precip-tiation	Precip-tiation	Evapor-ation	Evapor-ation	Storage Change	Storage Change	Estimated Seepage
Month	(MGD)	(cfs)	(in)	(cfs)	(in)	(cfs)	(ac-ft/mo)	(cfs)	(cfs)
JAN	0.412	0.638	5.82	0.157	0.98	0.026	8.6	0.141	0.628
FEB	0.356	0.552	2.21	0.064	2.1	0.061	-11.0	-0.198	0.753
MAR	0.309	0.479	0.1	0.003	3.89	0.105	3.8	0.062	0.315
APR	0.327	0.507	0.08	0.002	5.39	0.151	-26.3	-0.443	0.801
MAY	0.336	0.521	0.53	0.014	7.02	0.190	-10.1	-0.164	0.509
JUN	0.334	0.517	0	0.000	7.79	0.218	0.0	0.000	0.300
JUL	0.333	0.516	0	0.000	7.63	0.206	-15.3	-0.249	0.559
AUG	0.341	0.528	0	0.000	7.49	0.202	6.2	0.100	0.225
SEP	0.345	0.535	0	0.000	5.48	0.153	-4.8	-0.082	0.463
OCT	0.321	0.497	0.56	0.015	3.69	0.100	2.4	0.039	0.374
NOV	0.318	0.493	1.63	0.046	1.55	0.043	5.0	0.085	0.410
DEC	0.324	0.502	2.37	0.064	0.83	0.022	2.9	0.047	0.497
Average		0.524		0.030		0.123		-0.055	0.486
Notes:									
Data are for 2008.									
Precipitation is data from the climate station at Pardee Reservoir, 8 miles southeast of the WWTP.									
Evaporation is reference ET data from the CIMIS station at Fair Oaks, 28 miles north of the WWTP.									
Storage change is based on pond elevations reported in WWTP log books.									
All conversions from inches to cfs are based on the following pond areas:									
Pond No.	1	2	3	4	5	6	7		
Area (ac):	1.61	1.42	1.12	2.14	4.89	4.18	4.59		